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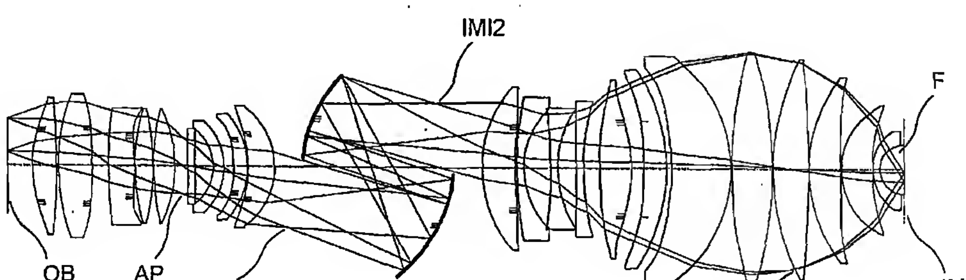
[Continued on next page]

(54) **Title:** OBJECTIVE AS A MICROLITHOGRAPHY PROJECTION OBJECTIVE WITH AT LEAST ONE LIQUID LENS



(57) **Abstract:** The invention relates to an objective designed as a microlithography projection objective for an operating wavelength. The objective has a greatest adjustable image-side numerical aperture NA, at least one first lens made from a solid transparent body, in particular glass or crystal, with a refractive index n_L and at least one liquid lens (F) made from a transparent liquid, with a refractive index NF. At the operating wavelength the first lens has the greatest refractive index n_L of all solid lenses of the objective, the refractive index n_F of the at least one liquid lens (F) is bigger than the refractive index n_L of the first lens and the value of the numerical aperture NA is bigger than 1.

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OBJECTIVE AS A MICROLITHOGRAPHY PROJECTION OBJECTIVE WITH AT LEAST ONE LIQUID LENS

BACKGROUND OF THE INVENTION

Field of the invention

The complete disclosure of US Application Ser. No. 10/734,623 filed on December 15, 2003, International Application No. PCT/EP2004/005816 filed on May 28 2004, US Application Ser. No. 60/530,623 filed on December 19, 2003, US Application Ser. No. 60/530,978 filed on December 22, 2003, European Application No. 03256499.9 filed on October 15, 2003, US Application Ser. No. 60/544,967 filed on February 13, 2004, US Application Ser. No. 60/592,208 filed on July 29, 2004, US Application Ser. No. 60/568,006 filed on May 4, 2004, US Application Ser. No. 60/591,775 filed on July 27, 2004 and US Application Ser. No. 60/612,823 filed on September 24, 2004 is hereby incorporated.

The invention relates to an objective designed as a microlithography projection objective. The objective according to the invention comprises at least one liquid lens made from a transparent liquid.

Description of the Related Art

Microlithography projection objectives of multivarious design are known.

In all imaging systems, the smallest resolvable structural width is proportional to the numerical aperture NA at the image plane.

This, in turn, is proportional to the angle of incidence and the refractive index n_I of the medium through which the light falls onto the image plane.

By contrast with so-called dry objectives with gas (air, N_2, He and the like) or a vacuum with a refractive index of approximately 1.0, a material, in particular a

liquid, with a substantially higher refractive index is used as this medium in immersion systems.

For example, as far as is known for the wavelength 193 nm water has a refractive index $n_{H2O} = 1.44$.

High-index lenses with a refractive index much higher than 1.6 have been used in microlithography at wavelengths of greater than 365 nm, but they become incapable of use at the wavelengths of practical relevance such as 248 nm, 195 nm, 157 nm, since they are not sufficiently transparent, and so on. Lenses made from sapphire have a high refractive index but are birefringent, and this must be compensated in a complicated way and with limited success.

SUMMARY OF THE INVENTION

The inventors have recognized that, furthermore, the possible image-side numerical aperture NA is limited by the refractive index of the curved optical element next to the image plane.

Such an element can be provided as a liquid lens that can also serve simultaneously as immersion liquid, specifically with or without a plane-parallel separation plate. However, if the refractive index n_F thereof lags behind the refractive index n_L of the solid lenses used in the objective, the achievable NA remains still smaller, $NA < n_F$.

The difference is significant in the case of a 193 nm objective with lenses made from fused silica with $n_L = 1.56$ and with water as an immersion and a liquid lens with $n_F = 1.44$.

According to the invention, use is made in the objective of at least one liquid lens whose refractive index n_F is greater than the refractive index n_L of each solid lens in the objective. The first lens in the meaning of Claim 1 is the lens, arranged at

any desired location in the objective, made from the highest-index solid lens material which is used in the objective. As also in the embodiments shown, all the lenses - except for the liquid lens or lenses - consist in many cases of the same solid material.

With respect to lenses made from fused silica or calcium fluoride, which are established for microlithography projection objectives with the operating wavelengths of 248 nm, 193 nm, 157 nm, liquids with, for example, $n_F = 1.6$, $n_F = 1.65$ or $n_F = 1.8$ are suitable.

There is a corresponding result for other lens materials known for the deep UV (DUV) and vacuum UV, such as fluoride crystals BaF_2, SrF_2, LiF, NaF and others.

Although there are many developments of immersion liquids for applications in microlithography, it is clear at least in principle that H_2SO_4 (sulfuric acid), H_3PO_4 (phosphoric acid) and their solutions in H_2O (water) yield adjustable refractive indices of 1.5 - 1.8 at 193 nm in conjunction with suitable transmission. In addition, the corrosive action of these substances is substantially reduced with the aid of substitution of heavy isotopes, in particular deuterium. This is described inter alia in US Application Ser. No. 60/568,006.

Corrosion protection layers can be provided on the solid optical elements. This is disclosed inter alia in US Application Ser. No. 60/530,623.

Accordingly, an objective having the features of Claim 1 has surprisingly been found to be particularly advantageous. A microlithography projection objective with an image-side numerical aperture NA greater than 1, which is not accessible for a dry objective, is substantially relieved and extended as regards the possibilities for its optical design and correction when use is made of a liquid lens with a refractive index greater than the refractive index of the solid lenses. In the case of lenses made from different materials, the largest refractive index of all these

lenses is exceeded. A plane-parallel plate, in particular an end plate made from sapphire, for example, may have a higher refractive index, in this case.

Objectives are usually corrected for specific operating wavelengths and can be operated reasonably only at these wavelengths. The refractive indices of all materials vary with wavelength, and it is always the values for the operating wavelength which are used as a basis here. Other wavelengths can traverse the objective, for example for the purposes of measurement.

It has surprisingly been found that on the basis of the invention it is possible to design objectives with an NA greater than the refractive index n_L of every solid lens. This is also reflected in Claim 2.

The liquid lens can be an immersion at the same time, that is to say it can be in contact to the object to be exposed. Alternatively, it is possible for an optical element made from a solid transparent body, in particular an end plate, to be arranged there between.

The liquids of the liquid lens and of the immersion at the object can then be adapted to various conditions such as:

- in the case of the immersion:
    - rapid movement for step-and-scan
    - contact with materials of the wafer such as resist
    - contact with air
    - cleaning requirements for wafer processing after exposure

- in the case of the liquid lens:
    - contact with material of the adjacent solid lens

and be selected, accordingly.

Since the refractive indices n_F of the liquid lens and n_I of the immersion are lower bounds for the achievable NA, it is natural to prefer that $n_F = n_I$.

The effect of increasing the accessible NA caused by the liquid lens with high refractive index n_F becomes greatest when said lens is the last curved element on the image side.

Substantially hemispherical last lenses have proved in this case to be advantageous, since then the angle of incidence of the light varies relatively slightly over the lens surface and remains close to the normal to the curved surface. The critical angle of total reflection is thus effectively avoided.

Intermediate images in the objective are a measure by which the lens diameters can be kept small. The availability and the price of lens material and of finish-machined lenses in a quality suitable for microlithography projection objectives are very substantially relieved at lower diameters.

It is therefore to be pointed out that, otherwise than in the US classification 359/642 defined for LENS, here it is precisely also optical systems with an intermediate image, even several thereof, that are designated as an objective. Designs of objectives suitable for the invention are inter alia disclosed in US Application Ser. No. 60/544,967, US Application Ser. No. 60/592,208 and US Application Ser. No. 60/591,775.

The field flattening is a central problem with such an objective, being equivalent to a minimization of the Petzval sum.

Primarily for this purpose, but also for color correction (achromatization), a design as a catadioptric system comprising at least one curved mirror in addition to the lenses is advantageous. A combination of a negative lens and a concave mirror is particularly effective for color correction. Further possibilities for color correction are disclosed in US Application Ser. No. 60/530,978. Catadioptric systems frequently have folding mirrors, thereby permitting the light beams running to a

mirror to be separated from those returning therefrom. Such systems are also described and covered here.

However, all surfaces of the optical system are effective for correction when all mirrors are curved. This is possible, in particular, with an even number, especially 2, of curved mirrors. It is also possible in this case for the entire objective to be constructed along a common axis of symmetry in relation to which all the mirror and lens surfaces exhibit a rotationally symmetrical shape where light passes through. However, there is asymmetric edging in the region of the mirrors and, if appropriate, adjacent lenses. Adjustment and vibration resistance as well as installation space requirements of the objective profit from the common axis of symmetry.

It is favorable in this case if the objective comprises an image-side objective part arranged at the image-side end of the objective and an intermediate objective part preceding the image-side objective part with respect of the direction of the light moving from the object-side end to the image-side end of the objective. If not defined otherwise, this direction is the reference whenever a position of a component of the objective is defined. The intermediate objective part is containing mirrors and may be designed catoptrically as, for example, in fig. 1 - fig. 3, or catadioptrically as in the other embodiments. The image-side objective part, which is purely refractive, is providing the extreme aperture and comprises the liquid lens.

It did surprisingly turn out that this image side objective part advantageously has its pupil in the region of the beam path which is convergent in relation to the image plane, or, as described in Claim 11, that said pupil is located between the lens of the greatest diameter used and the image plane.

In this region, the strong positive refractive power which is required in order to produce the large angles of incidence at the image plane in accordance with the high NA is expediently distributed over a plurality of positive meniscus lenses

which are concave on the image side. Both chromatic aberrations and contributions to the Petzval sum are thereby reduced.

The inventors have established that the solid lens preceding the liquid lens according to the invention and defining the object-side surface of the liquid lens should be a meniscus lens whose center thickness (THICKNESS in accordance with the tables) is smaller than the difference of the radii of curvature (RADIUS) of the two lens surfaces. Such a meniscus lens having negative refractive power in the paraxial region makes a transition in part to an action of positive refractive power in the outer region where beams strike more steeply, that is from further outside, than the normal to the surface.

It is advantageous when the objective comprises an object-side objective part being arranged at the object-side end of the objective and producing an intermediate image on the object side of the intermediate objective part.

This permits, inter alia, greater freedom in configuring the passage of the light bundles next to the mirrors, and yields an additional diaphragm location which can well be situated in an air space and is therefore well suited as a stop-down aperture diaphragm.

It is to be seen in the embodiments that it is advantageous to provide lenses of low refractive power with a strongly modulated aspheric shape preceding this diaphragm plane and to provide a strongly curved meniscus lens subsequent to this diaphragm plane, the meniscus lens being concave on the diaphragm side.

It is clear that such high-aperture projection objectives for microlithography of very high resolution require intensive use of aspherics, since essential parameters for image correction are thereby provided.

Deliberate use is also made in the exemplary embodiments of very strong aspherics and those whose deviation from the spherical shape does not exhibit a monotonic profile over the distance from the optical axis.

As already mentioned, such aspherics are particularly advantageous in the object-side objective part.

It emerges in addition that in the image-side objective part some positive lenses yield particularly suitable arrangements of strong aspherics. These positive lenses are situated in the region of the steeply rising light bundle diameter between the negative lenses arranged near the intermediate image and the belly of the light bundle at the lens with the maximum of the diameter of the light bundle passing through.

The embodiments presented are partly of an experimental nature. However, to the person skilled in the art who compares these with similar design solutions known to him and derives modifications therefrom they yield clear-cut teachings from which he is able to modify designs of objectives.

The various designs of the individual embodiments make this clear, and can, of course, also be combined with one another and with other known designs in the meaning of the invention.

The exemplary embodiments are explained in more detail with the aid of the drawings, in which

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 to 6 respectively show a meridian section of an embodiment of an objective according to the invention.

DESCRIPTION OF THE PREFERRED EMBODYMENTS

In Fig. 1 to 6 marginal and principal rays are depicted for the object points nearest and furthest from the axis. Aspheric surfaces are marked twice with 3 lines at the contour.

The optical axis or the axis of symmetry of the curvatures of the surfaces is marked by dots and dashes.

In each case OB denotes the object plane. This corresponds to the surface (SURF) 0 in the tables. IM denotes the image plane and corresponds in each case to the surface of the highest number in the tables.

F respectively denotes the liquid lens according to the invention.

EP denotes an optional end plate.

IMI1 and IMI2 are the intermediate images.

AP denotes the position of the system aperture at which an adjustable diaphragm can be arranged and will also be referred to as diaphragm plane.

P denotes the pupil in an image-side objective part.

All embodiments shown are designed for the operating wavelength 193.4 nm (ArF Excimer Laser) and reduce by 1:4 - without limiting the invention thereto.

Tables 1a to 6a respectively give the design data for the drawing of the same number. Tables 1b to 6b respectively specify the aspheric data of the aspheric lens and mirror surfaces, which are identified in the drawings by three primes. The illustration is made using the Optik-Design-Software CODE V™ from Optical Research Associates and corresponds to their conventions.

In each embodiment shown in fig. 1 to 6 the objective comprise an object-side objective part, an image-side objective part and an intermediate objective part. The object-side objective part is situated at the object-side end of the objective. The image-side objective part is situated at the image-side end of the objective. The intermediate objective part is situated between the object-side objective part and the image-side objective part. In the embodiments the object-side objective part and the image side objective part are purely reflective. The intermediate objective part is catoptric or catadioptric.

In the embodiments of fig. 1 to fig. 3 the value of the numerical aperture NA = 1.4. The liquid of the lens F and the immersion have the same refractive index $n_F = n_I$ = 1.65. The material of the solid lenses is fused silica with an index of refraction n_L = 1.56.

The distance from the object plane OB to the image IM is 1250 mm and thereby a common value.

The image field is 26 mm x 5.5 mm, decentered by 4.66 mm. However, the correction state yields an RMS wave front error of this image field of approximately 10-20 per mil of the operating wavelength.

The lenses of the object-side objective part and the image side objective part are rotationally symmetrical in relation to a common axis of symmetry, with the two mirrors of the catoptric version of the intermediate objective part certainly being curved in an axially symmetrical fashion, but being edged asymmetrically.

The design of the objective will now be described in more detail with respect to the embodiment of fig. 1. Most of the features are also present at the embodiments of fig. 2 to 6, but will only be explained in some detail with respect to fig. 1.

The object-side objective part comprises an accessible diaphragm plane AP with the stop-down system diaphragm. Preceding the diaphragm plane AP there is a

particularly strongly modulated aspheric (surface 7 of table 1a/b). Subsequent to the diaphragm plane AP there is a meniscus lens which is concave on the side of the diaphragm plane AP (surfaces 15, 16 in table 1a).

The intermediate objective part is designed catoptrically and comprises two concave mirrors (surfaces 23, 24 in table 1a).

The image-side objective part subsequent to the second intermediate image IMI2 - the intermediate images are not corrected and do not form an image plane - begins with a positive lens group of single-lens design, forms a waist with a number of negative lenses, and has a positive lens group with many members which forms a massive belly.

Strongly modulated aspherics (inter alia, surface 36 in table 1a/b) are significant in the initial region of the positive lens group where the diameter of the light bundle and of the lenses are increasing. The middle of the belly is formed by the lens of greatest diameter (surface 41/42 in table 1a/b, height (SEMIDIAM, half lens diameter) 160 mm). The production of lithographic projection objectives is very economical with this lens diameter. The pupil P of the image-side objective part is, in a fashion typical of the objectives according to the invention, following this largest lens in the convergent beam path.

In the embodiment of fig. 1, the liquid lens F is formed between the surface 50 and the image plane IM (surface 52) and is at the same time the immersion. It is virtually hemispherical given the radius 34.6 mm and the thickness 30.1 + 3.0 = 33.1 mm. The ratio of radius to thickness is 1.05. The adjacent last fused silica lens is in this case a meniscus lens whose thickness of 10 mm is substantially smaller than the difference of the radii 66 mm - 34 mm (surfaces 49/50).

In the embodiment of fig. 2, once again the liquid lens F is at the same time likewise immersion. However, it is substantially flatter than the liquid lens F of fig.

1. Only in combination with the last fused silica lens, the liquid lens F forms an approximately hemispherical member.

Using a rather flat liquid lens F makes the exchange of the liquid simpler.

It has been established that a plane-parallel plate which separates the liquid lens F and the immersion is not critical for the optical function. This holds in particular when the refractive index of the plan-parallel plate is greater than the refractive indices n_F of the liquid lens F and n_I of the immersion.

Starting from the embodiment of fig. 1, fig. 3 shows an embodiment with such an end plate EP of refractive index $n_{EP} = 1.80$. By adapting the thickness, it can easily be exchanged for a plate made from sapphire with $n_{EP} = 1.92$.

In the embodiment of fig. 4 (table 4a/b) a catadioptric design is used for the intermediate objective part.

Given the same NA, n_F, n_L as the preceding embodiments, the image field is somewhat deviant with 22 x 5.2 mm and greater decentering of 5.753 mm.

In this embodiment two planar folding mirrors FM1 (surface 21) and FM2 (surface 31) are used as geometric beam splitters. Provided in a lateral arrangement are a concave mirror – surface 26 in table 4a/b - and lenses of negative refractive power through which the light passes twice. The surfaces 22-25 of these lenses are thus present once more specularly as 27 to 30 in table 4a/b, since they refract the light twice.

The high-index liquid lens F is also advantageously used with this quite different approach to the design of the microlithographic projection objective. In a way similar to fig. 1, it is designed here as "immersion lens", touching the object, between the surfaces 63 and 65.

The two embodiments of fig. 5 and fig. 6 for the first time exhibit objectives with the numerical aperture NA = 1.6 being greater than the refractive index n_L of the solid lenses used. The solid lenses are made from fused silica with n_L = 1.56. The refractive index of the liquid lens F is n_F = 1.80. Also these embodiments are corrected much better than in a diffraction-limited fashion, their image field being 20 mm x 4 mm at a decentering of 4.375 mm. The RMS wavefront error is below a tenth of the operating wavelength 193.4 mm.

Here, as well, the object-side objective part is purely refractive. It includes the accessible and stop-down diaphragm plane AP and strong aspherics preceding the diaphragm plane AP. Here these aspherics are two lenses of lesser refractive power but stronger modulation of the aspheric shape deviation, surfaces 5 and 8 in table 5a/b. Arranged subsequent to these aspherics is a likewise strongly curved meniscus lens, surfaces 10, 11 in table 5a/6.

The intermediate objective part is once again a prolate catadioptric objective with two concave mirrors, similar to fig. 1-3, but now with a positive field lens (surfaces 20, 21 in table 5a) preceding the second intermediate image IMI2.

The positive field lens replaces the positive first lens group present in fig. 1-3 in the image-side objective part.

The image-side objective part thus begins with a negative lens group and forms a belly with a multilens positive lens group. In the embodiment of fig. 5 the greatest lens diameter is reached with 165 mm at the lenses 30/31 and 32/33 as can be seen in table 5a. A plurality of positive meniscus lenses which are concave in relation to the image plane IM is arranged subsequent to these lenses. The pupil P of the image-side objective part lies in the region of these meniscus lenses. The last fused silica lens (surfaces 40, 41 of table 5a) on the image side is once again of negative refractive power in the paraxial region. This lens is formed as a meniscus lens with a concave surface on the image side whose thickness is 8.9 mm and thus smaller than the difference of the radii 58.8 mm - 37.8 mm = 21 mm.

In the embodiment of fig. 5, the liquid lens F is immersion at the same time, and thus abuts the image plane IM and the object, which is arranged there in order to exposed. This object can be, for example, a wafer. The radius of the spherical surface 41 is 37.8 mm and thus smaller than the thickness of 45.8 mm.

The sine of the angle of incidence is smaller than 0.89 at all surfaces. The catadioptric intermediate objective part is enlarging. The sines of the angles of incidence at the concave mirrors are below 0.45.

The embodiment of fig. 6 and table 6a/b comprise a 3.0 mm thick end plate EP made from sapphire. The liquid lens F is now formed between the surfaces 42, 43 of table 6a. Their thickness is 40.2 mm, the radius is 38.1 mm. The thickness is thus 105% of the radius.

It has thus been shown that liquid lenses F of high refractive index permit the design of high-quality projection objectives with extreme numerical apertures.

Multivarious approaches and instructions are thus given to the person skilled in the art in order to use this teaching for further developing different kinds of known approaches in designing objectives.

Table 1a

SURF	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0 = OB	∞	35.000000		1.00030168	66.000
1	∞	0.100881		1.00030168	77.003
2	173.279980	34.026411	SIO2V	1.56078570	90.000
3	-1081.359892	2.602590		1.00029966	90.000
4	284.316798	47.383982	SIO2V	1.56078570	95.000
5	-1674.306964	22.855576		1.00029966	95.000
6	577.261196	36.645573	SIO2V	1.56078570	76.354
7	-314.377359	0.999980		1.00029966	73.677
8	290.150309	25.000000	SIO2V	1.56078570	75.000
9	-348.828624	1.000000		1.00029966	75.000
10	357.767685	29.107951	SIO2V	1.56078570	75.000
11	-185.316330	18.309132		1.00029966	75.000
12	∞	0.000000		1.00029966	36.370
13	∞	10.000000	SIO2V	1.56078570	44.778
14	∞	24.909905		1.00029966	47.596
15	-65.374870	14.999947	SIO2V	1.56078570	50.000
16	-87.154980	13.643080		1.00029966	60.000
17	-175.112352	18.964687	SIO2V	1.56078570	65.000
18	-111.646867	1.049880		1.00029966	70.000
19	-155.839260	37.603622	SIO2V	1.56078570	80.000
20	-102.943508	0.099910		1.00029966	80.000
21	∞	40.000000		1.00029966	90.389
22	∞	209.622700		1.00029966	92.498
23	-166.402525	-209.622700	REFL	1.00029966	150.000
24	173.713446	209.622700	REFL	1.00029966	125.000
25	∞	40.000000		1.00029966	99.138
26	∞	0.100021		1.00029966	105.283
27	174.736655	46.035435	SIO2V	1.56078570	110.000
28	369.899337	2.484896		1.00029966	105.000
29	511.775400	10.000000	SIO2V	1.56078570	95.000
30	117.498299	37.368783		1.00029966	80.000
31	-690.607305	10.000000	SIO2V	1.56078570	80.000
32	153.845418	25.455370		1.00029966	80.000
33	20331.979093	10.000000	SIO2V	1.56078570	90.000
34	347.272006	22.437822		1.00029966	90.000
35	502.344250	44.143760	SIO2V	1.56078570	120.000
36	-231.373663	17.400867		1.00029966	120.000
37	-837.483770	31.483968	SIO2V	1.56078570	130.000
38	-254.746002	6.600316		1.00029966	135.000
39	-392.185232	82.775939	SIO2V	1.56078570	140.000
40	-196.513232	1.000000		1.00029966	155.000
41	610.397747	56.287416	SIO2V	1.56078570	160.000
42	-556.907407	0.999835		1.00029966	160.000
43	296.607308	48.957456	SIO2V	1.56078570	150.000
44	-1578.327293	1.000000		1.00029966	150.000
45	216.352446	43.826306	SIO2V	1.56078570	125.000
46	2322.892305	1.000000		1.00029966	125.000
47	101.534703	42.624105	SIO2V	1.56078570	88.000
48	255.691515	0.999893		1.00029966	85.000
49	66.827516	10.000000	SIO2V	1.56078570	52.000
50	34.581844	30.092080	(F)	1.65000000	34.000
51	∞	3.000000	(F)	1.65000000	34.000
52 = IM	∞				34.000

Table 1b

ASPHERIC ONSTANTS

SRF	2	5	7	17	19
K	0	0	0	0	0
C1	-5.719118e-08	-1.218375e-07	4.192613e-07	-2.035191e-07	6.581837e-08
C2	-6.011473e-13	9.454546e-12	4.225479e-12	-2.746520e-11	1.290762e-11
C3	-2.863941e-16	-1.629731e-15	1.483284e-15	-2.529717e-15	6.638127e-16
C4	2.205921e-20	1.088963e-19	3.420546e-19	5.381454e-19	-2.943367e-19
C5	-5.981074e-24	8.373344e-24	-2.828899e-23	-1.447893e-22	3.550178e-24
C6	1.047361e-27	-1.832764e-27	-1.680731e-27	-3.175732e-27	6.050767e-28
C7	-1.013527e-31	1.046373e-31	2.906586e-31	5.176529e-30	4.358568e-31
C8	4.076124e-36	-1.708389e-36	-5.252329e-35	-1.024665e-33	-4.270946e-35

SRF	23	24	28	36	37
K	-0.602272	-0.240254	0	0	0
C1	0.000000e+00	0.000000e+00	-1.628020e-07	2.060497e-08	-7.918942e-08
C2	-9.110764e-15	3.799619e-15	5.004648e-12	6.206171e-13	-7.390346e-13
C3	-6.923032e-20	1.050462e-19	1.238115e-16	1.568846e-16	1.677228e-16
C4	-1.592422e-23	2.407529e-23	1.345805e-20	-1.970417e-20	-6.727857e-21
C5	8.704660e-28	-2.336605e-27	-5.722714e-24	2.817612e-24	6.703292e-25
C6	-3.848813e-32	2.089863e-31	7.429779e-28	-2.065939e-28	-1.712552e-29
C7	8.257231e-37	-8.540536e-36	-5.390293e-32	7.979829e-33	-9.430098e-34
C8	-7.590177e-42	1.725784e-40	1.988577e-36	-1.039469e-37	4.239222e-38

SRF	39	43	46
K	0	0	0
C1	5.160606e-09	-2.788258e-08	-2.365786e-08
C2	-2.393183e-13	4.064341e-13	3.640299e-12
C3	-7.204528e-17	2.762083e-17	-1.570433e-16
C4	-1.517240e-22	-4.172618e-22	6.381899e-21
C5	-3.032479e-27	-3.754486e-27	-3.770869e-26
C6	1.227351e-29	-6.324033e-31	-1.116749e-29
C7	-8.867490e-34	3.185590e-35	6.455153e-34
C8	2.067251e-38	-4.120762e-40	-1.076920e-38

Table 2a

SURF	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0 = OB	∞	35.000000		1.00030168	66.000
1	∞	1.166644		1.00030168	77.003
2	197.911058	20.674095	SIO2V	1.56078570	90.000
3	635.116021	2.894278		1.00029966	90.000
4	154.515346	52.818599	SIO2V	1.56078570	95.000
5	-674.545898	46.213532		1.00029966	95.000
6	351.508267	12.006164	SIO2V	1.56078570	76.354
7	-355.431508	1.879459		1.00029966	73.677
8	137.853261	42.368303	SIO2V	1.56078570	75.000
9	-168.451126	1.576637		1.00029966	75.000
10	∞	18.000000		1.00029966	36.370
11	∞	10.000000	SIO2V	1.56078570	44.778
12	∞	25.245183		1.00029966	47.596
13	-69.535170	15.000107	SIO2V	1.56078570	50.000
14	-125.326320	1.000069		1.00029966	60.000
15	-178.873389	25.788410	SIO2V	1.56078570	65.000
16	-101.720844	15.664259		1.00029966	70.000
17	-199.223616	36.639577	SIO2V	1.56078570	80.000
18	-102.251112	0.099749		1.00029966	80.000
19	∞	40.000000		1.00029966	90.389
20	∞	209.622700		1.00029966	92.498
21	-166.119896	-209.622700	REFL	1.00029966	150.000
22	175.984040	209.622700	REFL	1.00029966	125.000
23	∞	40.000000		1.00029966	99.138
24	∞	0.172730		1.00029966	105.283
25	253.724164	38.159409	SIO2V	1.56078570	110.000
26	-576.959427	1.129890		1.00029966	110.000
27	969.471804	12.758546	SIO2V	1.56078570	105.000
28	349.602989	0.999948		1.00029966	105.000
29	528.180407	10.000000	SIO2V	1.56078570	95.000
30	121.034243	37.709281		1.00029966	80.000
31	-511.453381	10.000000	SIO2V	1.56078570	80.000
32	144.865830	27.748574		1.00029966	80.000
33	-2683.436282	10.000000	SIO2V	1.56078570	90.000
34	350.818886	21.231421		1.00029966	90.000
35	564.353180	43.838798	SIO2V	1.56078570	120.000
36	-231.828235	17.071926		1.00029966	120.000
37	-844.682254	27.174378	SIO2V	1.56078570	130.000
38	-257.084208	13.572085		1.00029966	135.000
39	-347.360290	79.971864	SIO2V	1.56078570	140.000
40	-191.420105	1.000000		1.00029966	155.000
41	638.593875	53.484057	SIO2V	1.56078570	160.000
42	-617.708478	0.999739		1.00029966	160.000
43	290.550562	51.321670	SIO2V	1.56078570	150.000
44	-1239.997337	1.000000		1.00029966	150.000
45	234.055441	41.191419	SIO2V	1.56078570	125.000
46	1260.796700	1.000000		1.00029966	125.000
47	119.116897	46.087832	SIO2V	1.56078570	92.000
48	410.714306	0.999596		1.00029966	90.000
49	57.007308	19.999880	SIO2V	1.56078570	52.000
50	70.000000	24.719485	(F)	1.65000000	48.000
51	∞	3.000000	(F)	1.65000000	34.000
52 = IM	∞				34.000

Table 2b

ASPHERIC CONSTANTS

SRF	2	5	7	15	17
K	0	0	0	0	0
C1	-4.272071e-08	-6.660852e-08	4.612425e-07	-1.819217e-07	-2.134272e-08
C2	-2.130756e-12	5.070507e-12	1.287676e-11	-1.679339e-11	2.642130e-12
C3	-3.407494e-16	-7.615346e-16	2.169742e-15	-4.541462e-15	3.144530e-16
C4	4.132704e-20	7.606615e-20	3.202709e-19	1.365731e-18	-1.203833e-19
C5	-8.614408e-24	5.842474e-24	1.189789e-22	-7.298537e-22	3.777303e-23
C6	1.402057e-27	-1.689387e-27	-4.328782e-26	1.116111e-25	-6.878338e-27
C7	-1.320281e-31	1.280496e-31	5.025746e-30	4.239480e-31	6.547727e-31
C8	6.029685e-36	-3.499149e-36	-2.455352e-34	-2.801453e-33	-2.572158e-35

SRF	21	22	28	36	37
K	-0.673243	-0.223377	0	0	0
C1	0.000000e+00	0.000000e+00	-1.742865e-07	-1.146354e-09	-8.904146e-08
C2	-1.542990e-14	4.242474e-15	3.989651e-12	6.487508e-13	-9.704035e-13
C3	-2.283008e-19	-1.633115e-19	2.232371e-16	2.106572e-16	1.932349e-16
C4	-2.701974e-23	7.966751e-23	-2.851297e-20	-1.981895e-20	-9.140962e-21
C5	1.563798e-27	-8.898817e-27	1.148424e-24	2.432642e-24	7.612481e-25
C6	-7.092827e-32	6.276885e-31	3.102982e-28	-1.327579e-28	-5.817189e-30
C7	1.654890e-36	-2.262895e-35	-5.058499e-32	4.126250e-33	-1.250231e-33
C8	-1.695530e-41	3.532661e-40	3.007511e-36	-3.753435e-38	3.610689e-38

SRF	39	43	46
K	0	0	0
C1	6.669745e-09	-3.063876e-08	-3.402805e-08
C2	1.190421e-13	3.642882e-13	4.126635e-12
C3	-7.888065e-17	2.784805e-17	-1.931151e-16
C4	-5.882168e-23	-6.429270e-22	8.149530e-21
C5	2.413262e-26	8.661549e-27	-7.144438e-26
C6	8.242901e-30	-8.015685e-31	-1.341671e-29
C7	-6.256631e-34	2.825051e-35	7.855498e-34
C8	1.445073e-38	-3.170258e-40	-1.361588e-38

Table 3a

SURF	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0 = OB	∞	35.000000		1.00030168	66.000
1	∞	0.099980		1.00030168	77.003
2	170.078547	36.468596	SIO2V	1.56078570	90.000
3	-599.314872	2.182511		1.00029966	90.000
4	333.623154	49.026243	SIO2V	1.56078570	95.000
5	-5357.879827	17.783452		1.00029966	95.000
6	524.085081	39.656864	SIO2V	1.56078570	76.354
7	-372.985082	1.020916		1.00029966	73.677
8	273.494931	25.000000	SIO2V	1.56078570	75.000
9	-304.985535	1.000000		1.00029966	75.000
10	326.223899	32.555959	SIO2V	1.56078570	75.000
11	-194.836449	18.000006		1.00029966	75.000
12	∞	0.000000		1.00029966	36.370
13	∞	10.000000	SIO2V	1.56078570	44.778
14	∞	24.420303		1.00029966	47.596
15	-65.482398	15.000019	SIO2V	1.56078570	50.000
16	-89.830925	12.487606		1.00029966	60.000
17	-181.375682	17.778805	SIO2V	1.56078570	65.000
18	-112.069227	1.008243		1.00029966	70.000
19	-158.283947	37.090377	SIO2V	1.56078570	80.000
20	-102.436390	0.099969		1.00029966	80.000
21	∞	40.000000		1.00029966	90.389
22	∞	209.622700		1.00029966	92.498
23	-166.136319	-209.622700	REFL	1.00029966	150.000
24	173.615104	209.622700	REFL	1.00029966	125.000
25	∞	40.000000		1.00029966	99.138
26	∞	0.104935		1.00029966	105.283
27	161.705740	39.665166	SIO2V	1.56078570	110.000
28	338.219127	4.220151		1.00029966	105.000
29	539.284856	10.000000	SIO2V	1.56078570	95.000
30	115.279475	38.192763		1.00029966	80.000
31	-713.073292	10.000000	SIO2V	1.56078570	80.000
32	153.450259	25.766812		1.00029966	80.000
33	-35457.805610	10.000000	SIO2V	1.56078570	90.000
34	338.447211	22.577058		1.00029966	90.000
35	488.793543	45.370961	SIO2V	1.56078570	120.000
36	-229.090765	17.224093		1.00029966	120.000
37	-813.380443	31.337371	SIO2V	1.56078570	130.000
38	-255.856356	9.074786		1.00029966	135.000
39	-397.181958	81.335823	SIO2V	1.56078570	140.000
40	-197.104943	1.000000		1.00029966	155.000
41	616.283620	55.915659	SIO2V	1.56078570	160.000
42	-558.051853	0.999900		1.00029966	160.000
43	297.754439	48.959126	SIO2V	1.56078570	150.000
44	-1599.554010	1.000000		1.00029966	150.000
45	216.813876	43.986900	SIO2V	1.56078570	125.000
46	2513.355923	1.000000		1.00029966	125.000
47	102.047705	42.326072	SIO2V	1.56078570	88.000
48	258.213934	1.000000		1.00029966	85.000
49	67.045666	10.000000	SIO2V	1.56078570	52.000
50	33.992537	27.639900	(F)	1.65000000	33.000
51	∞	3.000000		1.80000000	33.000
52	∞	3.000000	(IMMERS.)	1.65000000	33.000
53 = IM	∞				33.000

Table 3b

ASPHERIC CONSTANTS

SRF	2	5	7	17	19
K	0	0	0	0	0
C1	-6.761238e-08	-1.339952e-07	4.322957e-07	-1.865717e-07	5.694739e-08
C2	-2.795074e-13	8.081896e-12	6.638487e-12	-2.605817e-11	1.297663e-11
C3	-3.419978e-16	-1.520519e-15	1.196137e-15	-2.223425e-15	7.551094e-16
C4	3.593975e-20	1.158356e-19	3.139076e-19	4.529397e-19	-2.801640e-19
C5	-7.394770e-24	8.165985e-24	-2.103438e-23	-1.036163e-22	-1.293839e-24
C6	1.067458e-27	-2.018394e-27	-2.540248e-27	-6.085859e-27	7.867948e-28
C7	-9.043542e-32	1.252003e-31	3.764879e-31	4.354732e-30	4.763906e-31
C8	3.329797e-36	-2.409824e-36	-5.551249e-35	-7.881442e-34	-4.577122e-35

SRF	23	24	28	36	37
K	-0.603427	-0.236665	0	0	0
C1	0.000000e+00	0.000000e+00	-1.724255e-07	1.725752e-08	-8.279489e-08
C2	-1.058224e-14	3.699741e-15	4.976445e-12	5.471441e-13	-8.022210e-13
C3	-1.413269e-19	-3.750775e-20	2.387092e-16	1.390990e-16	1.431148e-16
C4	-1.204112e-23	5.430640e-23	5.525729e-21	-1.755950e-20	-5.767930e-21
C5	4.963866e-28	-5.801174e-27	-6.052665e-24	2.625696e-24	6.871766e-25
C6	-2.129066e-32	4.279164e-31	7.725095e-28	-1.914617e-28	-2.240962e-29
C7	3.795477e-37	-1.574698e-35	-5.045738e-32	7.395971e-33	-3.639715e-34
C8	-2.918284e-42	2.685481e-40	1.564423e-36	-7.980691e-38	3.135529e-38

SRF	39	43	46
K	0	0	0
C1	5.939680e-09	-2.752287e-08	-2.413171e-08
C2	-2.375134e-13	4.114456e-13	3.695674e-12
C3	-6.806224e-17	2.737675e-17	-1.621470e-16
C4	-8.082613e-23	-3.526372e-22	6.681382e-21
C5	-1.967221e-26	-7.704679e-27	-4.618168e-26
C6	1.266402e-29	-4.719101e-31	-1.117841e-29
C7	-8.622711e-34	2.794633e-35	6.554350e-34
C8	1.902299e-38	-3.716332e-40	-1.099816e-38

Table 4a

SURF	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0 = OB	∞	101.496840			62.000
1	-523.184936	27.851984	SIO2	1.56032610	96.419
2	-210.066935	0.999968			99.916
3	143.399781	52.055602	SIO2	1.56032610	115.102
4	345.776862	35.383042			110.966
5	168.075295	52.902563	SIO2	1.56032610	95.593
6	-581.011371	0.099991			85.017
7	82.494445	46.014670	SIO2	1.56032610	65.623
8	74.608756	18.376623			43.366
9	∞	0.000000	SIO2	1.56032610	40.333
10	∞	9.898700			40.333
11	-93.661632	25.608969	SIO2	1.56032610	40.388
12	-97.944812	42.548618			50.610
13	-63.503040	54.172316	SIO2	1.56032610	58.454
14	-94.409957	1.264244			87.595
15	-328.877474	40.537580	SIO2	1.56032610	104.907
16	-131.896136	1.001643			106.846
17	204.370502	42.653441	SIO2	1.56032610	107.596
18	-2747.675446	1.723900			105.816
19	216.208053	27.952948	SIO2	1.56032610	97.813
20	2712.784924	99.872557			94.335
21 = FM1	∞	-160.545313	REFL		27.154
22	101.244286	-12.500000	SIO2	1.56032610	72.986
23	628.850173	-53.212241			88.277
24	102.805812	-12.500000	SIO2	1.56032610	91.193
25	200.305727	-25.464217			119.887
26	150.933505	25.464217	REFL		122.686
27	200.305727	12.500000	SIO2	1.56032610	119.499
28	102.805812	53.212241			90.105
29	628.850173	12.500000	SIO2	1.56032610	85.671
30	101.244286	160.545353			71.821
31 = FM2	∞	-109.999623	REFL		134.552
32	862.422907	-30.130833	SIO2	1.56032610	102.165
33	229.773890	-0.999915			105.942
34	-617.789022	-35.509195	SIO2	1.56032610	118.697
35	565.469461	-0.999931			120.255
36	-246.806971	-44.859593	SIO2	1.56032610	124.965
37	32400.831779	-0.099930			123.417
38	-158.610832	-71.070427	SIO2	1.56032610	112.458
39	-1341.469728	-8.796304			98.473
40	3541.685396	-11.999956	SIO2	1.56032610	96.987
41	-126.167849	-44.791303			78.038
42	469.858200	-11.999957	SIO2	1.56032610	78.204
43	-108.758112	-27.637030			84.487
44	-1480.509587	-15.438600	SIO2	1.56032610	86.624
45	2433.499100	-49.439954			90.710
46	-1932.185692	-25.660740	SIO2	1.56032610	119.141
47	428.080551	-0.999961			123.769
48	-408.475637	-36.662820	SIO2	1.56032610	147.587
49	-16389.465356	-7.335981			148.838
50	-342.428932	-60.116835	SIO2	1.56032610	158.305
51	658.847066	-0.091541			157.731
52	∞	0.000000	SIO2	1.56032610	156.315
53	∞	-2.670708			156.315

Table 4a (cont.)

54	-702.444090	-32.792626	SIO2	1.56032610	155.963
55	1222.808780	-0.999915			155.470
56	-309.712976	-41.860232	SIO2	1.56032610	144.999
57	3694.385507	-0.999819			144.012
58	-135.513673	-31.965622	SIO2	1.56032610	109.063
59	-185.513505	-0.999775			103.967
60	-88.090936	-38.540831	SIO2	1.56032610	80.707
61	-187.712668	-0.999577			73.736
62	-58.692832	-9.999803	SIO2	1.56032610	51.770
63	-33.167937	-38.114503	(F)	1.65000000	33.117
64	∞	-3.000000	(F)	1.65000000	20.048
65 = IM	∞				15.841

Table 4b

ASPHERIC CONSTANTS

SRF	6	15	20	22	30
K	0	0	0	0	0
C1	1.190289e-07	-1.976769e-08	4.403358e-08	-6.572731e-08	-6.572731e-08
C2	-2.160947e-12	1.109889e-12	8.071972e-17	-4.743844e-12	-4.743844e-12
C3	6.852608e-16	-3.889116e-17	3.366541e-18	-9.012440e-18	-9.012440e-18
C4	-3.837379e-20	-1.882901e-21	5.100729e-22	-1.597994e-19	-1.597994e-19
C5	1.217764e-25	1.332477e-25	-4.259657e-26	2.141145e-23	2.141145e-23
C6	2.211313e-28	-2.258521e-30	2.686157e-30	-2.250289e-27	-2.250289e-27

SRF	39	41	43	46	51
K	0	0	0	0	0
C1	1.699431e-08	-2.143897e-07	2.168103e-07	3.156834e-08	-7.013045e-09
C2	-9.046901e-12	2.732198e-12	1.367067e-12	3.487654e-13	5.963914e-16
C3	1.128480e-15	-1.371285e-15	3.062347e-16	-1.560492e-17	-1.630073e-17
C4	-9.595855e-20	-1.137997e-19	5.350290e-20	1.140928e-21	5.396066e-22
C5	5.011204e-24	2.693954e-23	-4.811379e-24	-4.815997e-26	-7.602819e-27
C6	-1.196219e-28	-3.312568e-27	4.970104e-28	5.836063e-31	4.085943e-32

SRF	59	61
K	0	0
C1	4.429013e-08	-9.119846e-08
C2	-4.664097e-12	-9.933832e-12
C3	3.978191e-16	4.577490e-16
C4	-1.307434e-20	-2.618132e-19
C5	-5.651715e-25	5.019446e-23
C6	3.529575e-29	-5.414482e-27

Table 5a

SURF	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0 = OB	∞	31.284792			52.000
1	194.413567	32.720399	SIO2V	1.56078570	74.615
2	-837.875926	6.370734			74.349
3	95.475130	26.728836	SIO2V	1.56078570	70.388
4	148.726918	30.489652			65.856
5	1084.901978	14.117445	SIO2V	1.56078570	60.419
6	-329.264238	0.743287			58.910
7	372.368293	15.458004	SIO2V	1.56078570	54.832
8	-148.979042	27.240305			52.113
9	∞	32.301644			43.951
10	-57.723183	31.449460	SIO2V	1.56078570	47.695
11	-71.150453	0.929754			62.740
12	383.639393	22.046149	SIO2V	1.56078570	83.185
13	-904.695268	0.905975			84.675
14	179.698033	38.448563	SIO2V	1.56078570	90.818
15	-389.247961	29.862111			90.050
16	∞	258.234067			85.109
17	-151.387947	-258.234067	REFL		103.744
18	258.267631	258.234067	REFL		180.342
19	∞	29.981280			116.992
20	251.052546	31.241091	SIO2V	1.56078570	101.576
21	-6016.827917	77.406555			98.554
22	-125.618112	8.960662	SIO2V	1.56078570	70.289
23	129.125754	28.406854			68.882
24	-681.780853	8.898731	SIO2V	1.56078570	70.634
25	205.568565	41.577461			78.503
26	-183.215344	15.843375	SIO2V	1.56078570	82.563
27	-747.008350	6.201177			102.654
28	1186.195936	72.658205	SIO2V	1.56078570	120.160
29	-156.971444	0.905847			126.492
30	648.451941	66.013805	SIO2V	1.56078570	163.810
31	-396.824326	25.988117			165.175
32	289.870283	40.412480	SIO2V	1.56078570	163.677
33	480.887470	0.928925			161.538
34	178.362272	40.967739	SIO2V	1.56078570	144.125
35	253.519298	0.947294			138.643
36	154.855021	52.211656	SIO2V	1.56078570	125.560
37	522.613285	0.825571			119.129
38	100.582695	44.936735	SIO2V	1.56078570	88.620
39	272.608820	0.825571			79.210
40	58.829925	8.861393	SIO2V	1.56078570	52.876
41	37.856352	45.769132	(F)	1.80000000	37.564
42 = IM	∞				13.001

Table 5b

ASPHERIC CONSTANTS

SRF	1	5	8	15	17
K	0	0	0	0	0
C1	2.035368e-07	1.161173e-07	6.549025e-07	1.058964e-07	1.486128e-08
C2	2.122045e-13	-9.174854e-11	1.133907e-11	-1.960464e-12	6.224903e-13
C3	-1.232124e-15	9.078126e-15	2.931708e-14	-1.719346e-16	1.675590e-17
C4	6.485869e-20	-1.260952e-18	-8.285156e-18	2.217335e-20	1.269177e-21
C5	9.917577e-24	2.019305e-22	3.500031e-21	-1.159319e-24	-5.260128e-26
C6	-9.582163e-28	-7.811919e-27	3.522430e-26	2.527662e-29	4.654328e-30

SRF	18	22	25	28	33
K	-0.267731	0	0	0	0
C1	-7.023674e-10	4.605486e-07	2.881794e-07	-3.576109e-08	-1.085274e-08
C2	-9.477643e-15	-7.227058e-11	-4.494181e-11	8.140963e-13	1.115172e-13
C3	-7.423466e-20	1.056869e-14	-2.448411e-15	-3.935804e-17	-9.843842e-18
C4	-4.429195e-24	-1.243813e-18	9.621332e-19	-7.624420e-22	-1.420093e-22
C5	4.705745e-29	1.098424e-22	-9.474976e-23	1.473104e-25	1.350399e-26
C6	-1.008977e-33	-3.554283e-27	3.735014e-27	-5.284140e-30	-1.682167e-31

SRF	37	39
K	0	0
C1	2.842058e-08	1.106769e-07
C2	-9.189727e-15	2.940296e-12
C3	7.067187e-17	-8.536341e-17
C4	-5.862923e-21	4.590349e-20
C5	2.902121e-25	-8.754730e-24
C6	-4.976330e-30	5.665333e-28

Table 6a

SURF	RADIUS	THICKNESS	MATERIAL	INDEX	SEMIDIAM.
0 = OB	∞	31.284792			52.000
1	∞	0.000000			65.651
2	193.599182	32.235664	SIO2V	1.56078570	74.583
3	-988.153919	6.121005			74.317
4	95.312730	28.437060	SIO2V	1.56078570	70.720
5	149.958061	29.337945			65.762
6	990.600274	14.692793	SIO2V	1.56078570	60.664
7	-304.549723	0.925424			59.160
8	405.862783	15.231330	SIO2V	1.56078570	54.862
9	-150.695673	27.371286			52.107
10	∞	32.082969			43.913
11	-57.761263	34.954745	SIO2V	1.56078570	47.628
12	-73.049428	0.946034			64.468
13	371.078196	22.631363	SIO2V	1.56078570	85.710
14	-1054.171246	2.527973			87.142
15	176.905790	40.262309	SIO2V	1.56078570	93.860
16	-409.710820	29.670881			92.937
17	∞	262.083723			87.656
18	-152.961072	-262.083723	REFL		102.730
19	259.893027	262.083723	REFL		180.288
20	∞	40.275992			112.284
21	277.112135	28.048210	SIO2V	1.56078570	94.722
22	-1786.674721	65.923060			91.958
23	-115.766876	9.003310	SIO2V	1.56078570	70.538
24	143.904953	28.199458			69.827
25	-500.404643	8.993973	SIO2V	1.56078570	71.476
26	231.435891	40.923491			79.540
27	-194.421161	14.041869	SIO2V	1.56078570	83.835
28	-929.354406	6.572149			102.684
29	1551.636561	74.150055	SIO2V	1.56078570	118.556
30	-151.390217	0.924156			124.858
31	430.573439	62.728287	SIO2V	1.56078570	165.041
32	-668.844997	23.423849			165.694
33	303.567518	38.823785	SIO2V	1.56078570	163.062
34	524.212908	0.932060			160.960
35	176.353964	40.731123	SIO2V	1.56078570	143.422
36	247.491117	0.936510			137.926
37	153.122143	51.077607	SIO2V	1.56078570	124.946
38	412.041144	0.825571			118.371
39	101.547710	45.611823	SIO2V	1.56078570	89.393
40	315.478434	0.825571			80.057
41	58.429322	8.969645	SIO2V	1.56078570	53.083
42	38.144755	40.197998	(F)	1.80000000	37.922
43	∞	3.000000	SAPHIR	1.92650829	25.925
44	∞	4.345594	(IMMERS.)	1.80000000	21.446
45 = IM	∞				13.000

Table 6b

ASPHERIC CONSTANTS

SRF	2	6	9	16	18
K	0	0	0	0	0
C1	1.958847e-07	1.048404e-07	6.380918e-07	1.042335e-07	1.494444e-08
C2	8.684629e-13	-9.344654e-11	1.135337e-11	-1.647926e-12	6.329335e-13
C3	-1.177298e-15	9.684195e-15	2.969291e-14	-1.770077e-16	1.568829e-17
C4	5.172091e-20	-1.242151e-18	-8.230472e-18	1.938739e-20	1.153993e-21
C5	1.115087e-23	1.848517e-22	3.507973e-21	-8.862178e-25	-3.871456e-26
C6	-9.813899e-28	-8.222149e-27	3.205808e-26	1.726247e-29	3.672792e-30

SRF	19	23	26	29	34
K	-0.273225	0	0	0	0
C1	-4.825071e-10	5.116169e-07	3.252068e-07	-2.515552e-08	-1.130904e-08
C2	-6.621967e-15	-7.631783e-11	-4.649504e-11	1.947845e-13	2.463683e-13
C3	-6.600515e-20	1.115383e-14	-2.574578e-15	-1.814191e-17	-1.101814e-17
C4	-4.043335e-24	-1.308686e-18	1.022883e-18	-1.328934e-21	-2.972090e-22
C5	4.835743e-29	1.177910e-22	-9.907368e-23	1.639600e-25	1.942591e-26
C6	-1.092461e-33	-3.908759e-27	3.745941e-27	-5.808419e-30	-2.321607e-31

SRF	38	40
K	0	0
C1	2.336279e-08	1.464967e-07
C2	-1.224680e-12	1.974044e-12
C3	1.869425e-16	-4.637058e-16
C4	-1.001651e-20	1.216769e-19
C5	3.399061e-25	-1.544405e-23
C6	-4.264065e-30	7.169909e-28

Claims:

1. Objective designed as a microlithography projection objective for an operating wavelength,

- having a greatest adjustable image-side numerical aperture NA,
- having at least one first lens made from a solid transparent body, in particular glass or crystal, with a refractive index n_L,
- having at least one liquid lens (F) made from a transparent liquid, with a refractive index n_F,

wherein at the operating wavelength

- the first lens has the greatest refractive index n_L of all solid lenses of the objective,
- the refractive index n_F of the at least one liquid lens (F) is bigger than the refractive index n_L of the first lens
- and the value of the numerical aperture NA is bigger than 1.

2. Objective according to Claim 1, characterized in that at the operating wavelength the refractive indices n_F and n_L and the numerical aperture NA are related to each other according to $n_F > NA > n_L$.

3. Objective according to at least one of the preceding claims, characterized in that at the operating wavelength the numerical aperture $NA \geq 1.4$.

4. Objective according to at least one of the preceding claims, characterized in that the at least one liquid lens (F) is the last curved optical element on the image side.

5. Objective according to at least one of the preceding claims, characterized in that a plane-parallel plate (EP) is arranged between the at least one liquid lens (F) and the image plane (IM) of the objective.

6. Objective according to Claim 5, characterized in that at the operating wavelength the refractive index n_{EP} of the plane-parallel plate (EP) is greater than the refractive index n_F of the at least one liquid lens (F), in particular in that the plane-parallel plate consists of sapphire.

7. Objective according to at least one of the preceding claims, characterized in that the at least one liquid lens (F) is essentially hemispherical and, in particular, has a thickness on the optical axis of the objective that is 80 to 110% of the radius of its curved surface.

8. Objective according to at least one of the preceding claims, characterized in that it exhibits one or two intermediate images (IM1, IM2).

9. Objective according to at least one of the preceding claims, characterized in that it is catadioptric.

10. Objective according to at least one of the preceding claims, characterized in that it comprises an image-side objective part arranged at the image-side end of the objective and being refractive.

11. Objective according to Claim 10, characterized in that the pupil (P) of the image-side objective part is arranged between a lens at which the traversing light bundle is of greatest diameter and the image plane (IM).

12. Objective according to at least one of the preceding claims, characterized in that a number of meniscus lenses of positive refractive power, which have a concave shape on the image side, are preceding the at least one liquid lens (F).

13. Objective according to at least one of the preceding claims, characterized in that a stop-down system aperture is arranged in an object-side objective part, which is located at the object-side end of the objective.

14. Objective according to at least one of the preceding claims, characterized in that at the operating wavelength the refractive index n_F of the at least one liquid lens (F) is bigger than 1.4, preferably equal to or bigger than 1.6.

15. Objective according to at least one of the preceding claims, characterized in that it is a catadioptric objective for which all refracting or reflecting surfaces are rotationally symmetrical in relation to a common axis.

16. Objective according to at least one of the preceding claims, characterized in that it is a catadioptric objective and all the mirrors are curved.

17. Objective according to at least one of the preceding claims, characterized in that it comprises a catoptric or catadioptric objective part.

18. Objective according to at least one of the preceding claims, characterized in that it comprises a catadioptric objective part with a concave mirror and a negative lens.

19. Objective according to at least one of the preceding claims, characterized in that it is an immersion objective.

20. Objective according to at least one of the preceding claims, characterized in that at least one liquid lens (F) touches the image plane (IM) and an object, if the object is arranged in the image plane in order to be exposed.

21. Objective according to at least one of the preceding claims, characterized in that it includes an object-side last element made from a transparent solid body, in particular a plane-parallel plate (EP) according to Claim 5 or 6, and in that a transparent medium with a refractive index $n_I > 1.1$ at the operating wavelength is arranged between this element and an object in the region of the image plane (IM).

22. Objective according to Claim 21, characterized in that at the operating wavelength it holds that $n_I = n_F$.

23. Objective according to Claim 21 or Claim 22, characterized in that at the operating wavelength it holds that $n_I \geq n_L$.

24. Objective according to at least one of the preceding claims, characterized in that a material of the first lens or further lenses is a material from the group of fused silica and fluoride monocrystals comprising CaF_2, BaF_2, SrF_2, LiF, NaF.

ABSTRACT

The invention relates to an objective designed as a microlithography projection objective for an operating wavelength. The objective has a greatest adjustable image-side numerical aperture NA, at least one first lens made from a solid transparent body, in particular glass or crystal, with a refractive index n_L and at least one liquid lens (F) made from a transparent liquid, with a refractive index n_F. At the operating wavelength the first lens has the greatest refractive index n_L of all solid lenses of the objective, the refractive index n_F of the at least one liquid lens (F) is bigger than the refractive index n_L of the first lens and the value of the numerical aperture NA is bigger than 1.

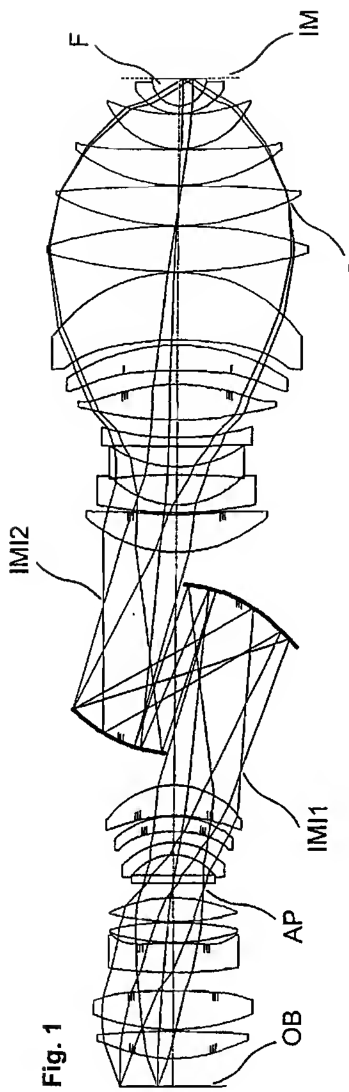

Fig. 1

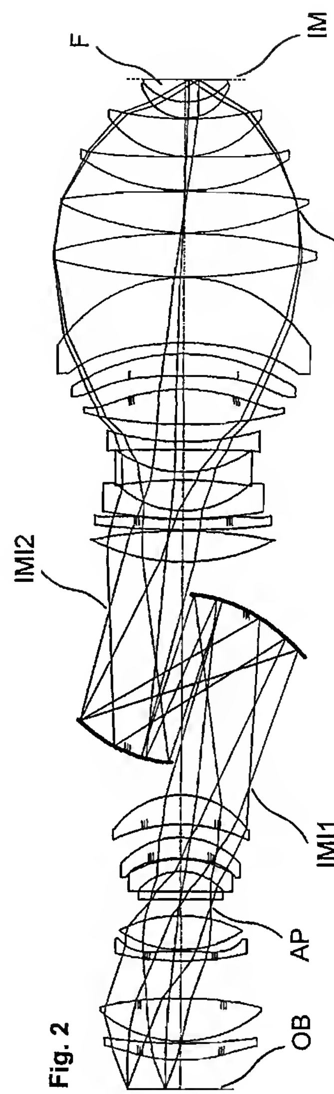

Fig. 2

2/3

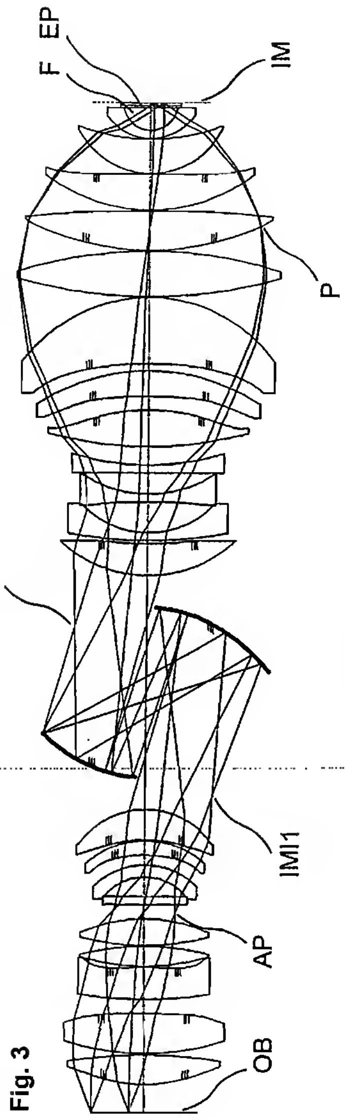

Fig. 3

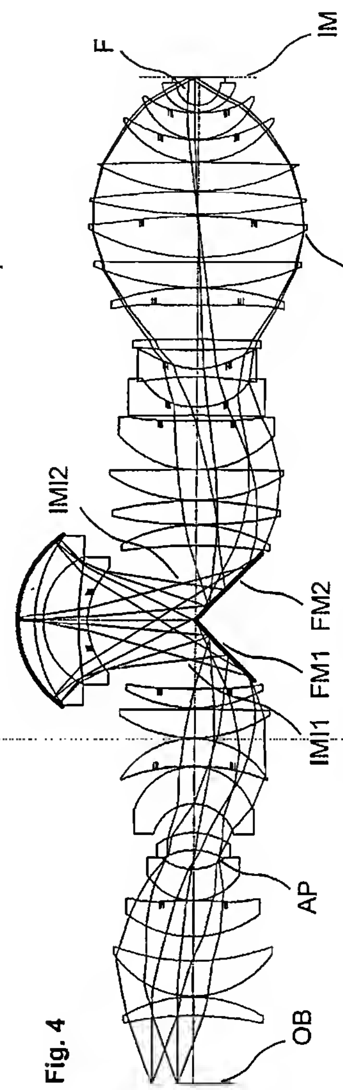

Fig. 4

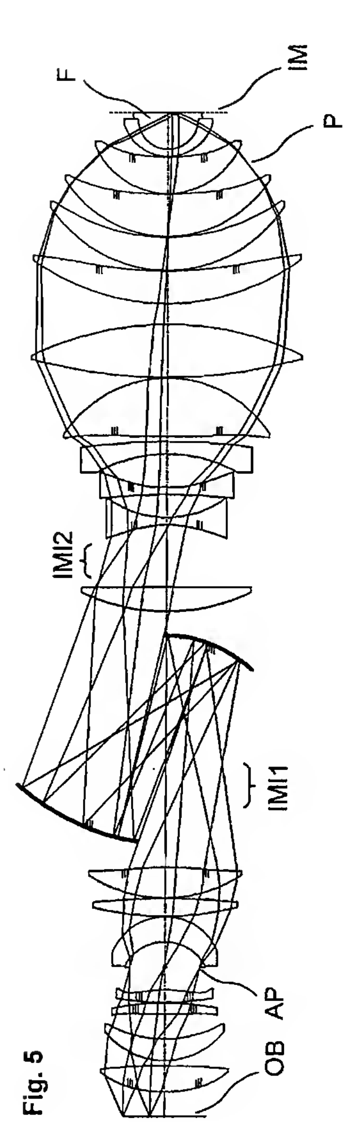

Fig. 5

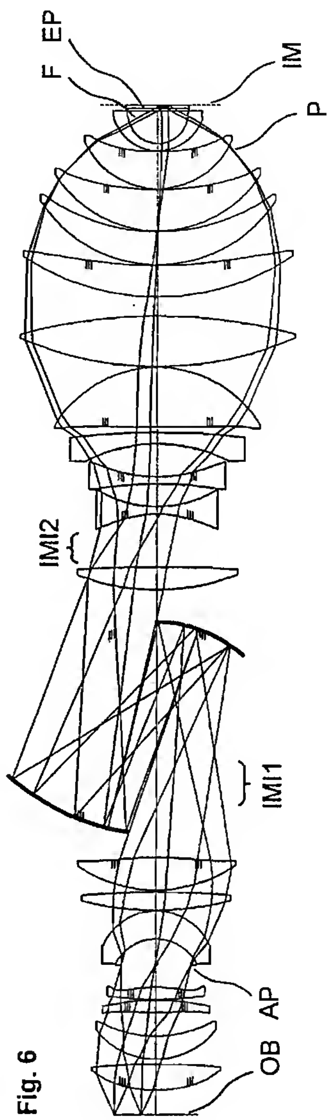

Fig. 6